A MICE muon identifier based on the KLOE calorimeter design

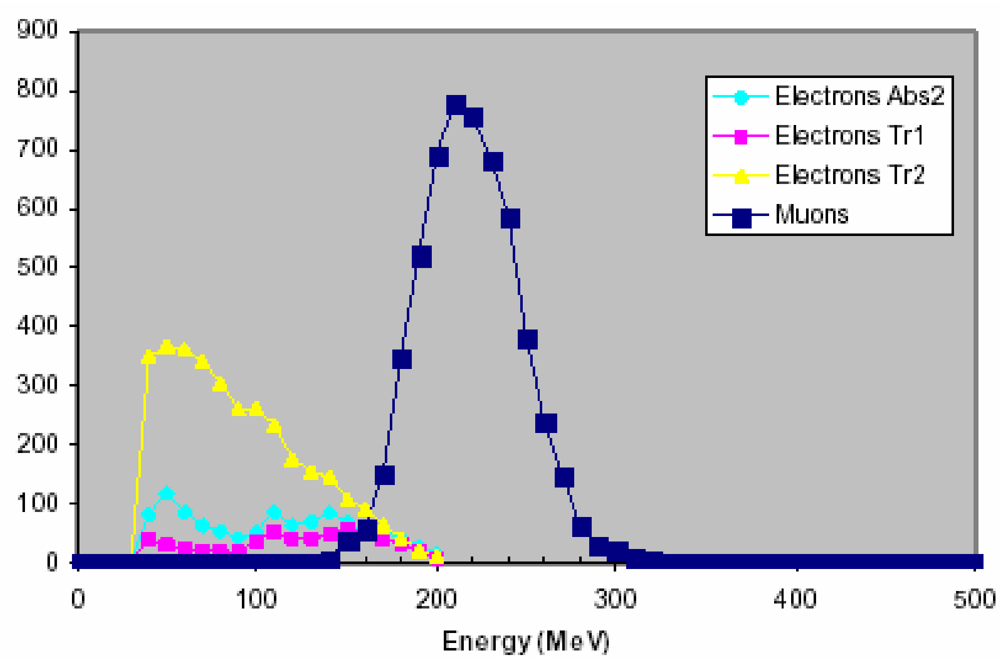
- The task
- Detector concept
- Technical drawings
- Simulation and PID

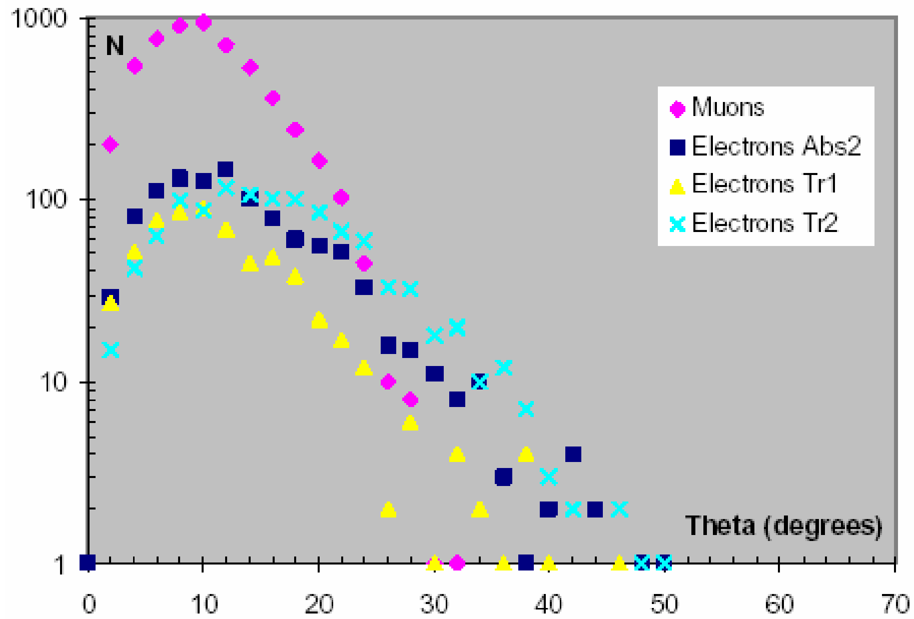
The task

➔ Provide “final” muon tag with highest possible Efficiency and Purity > 99.9%

Spectra and energy distributions:

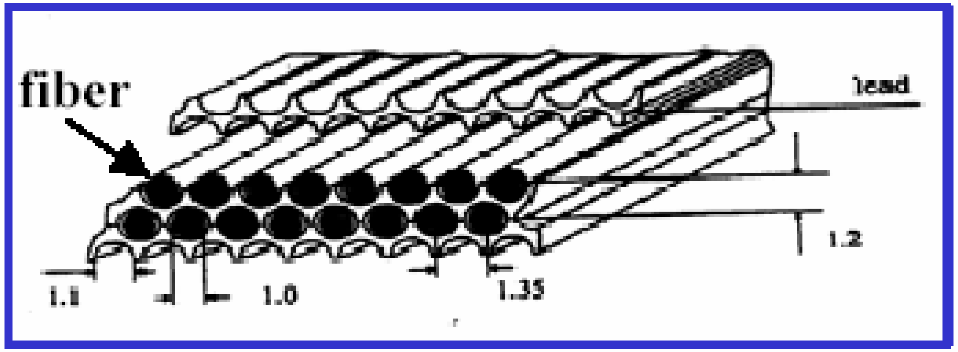
- Softer particles than previously estimated
- Electrons are more spread out than muons





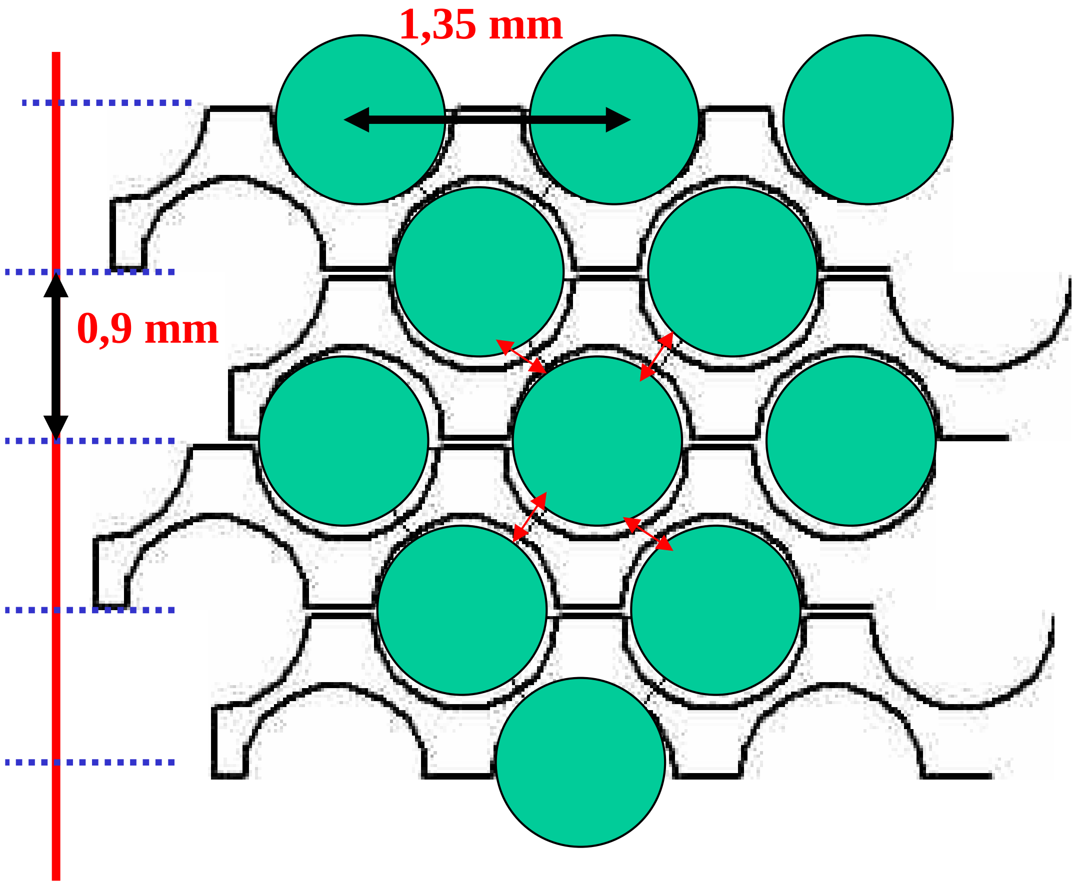
Fine-grained calorimeter technique

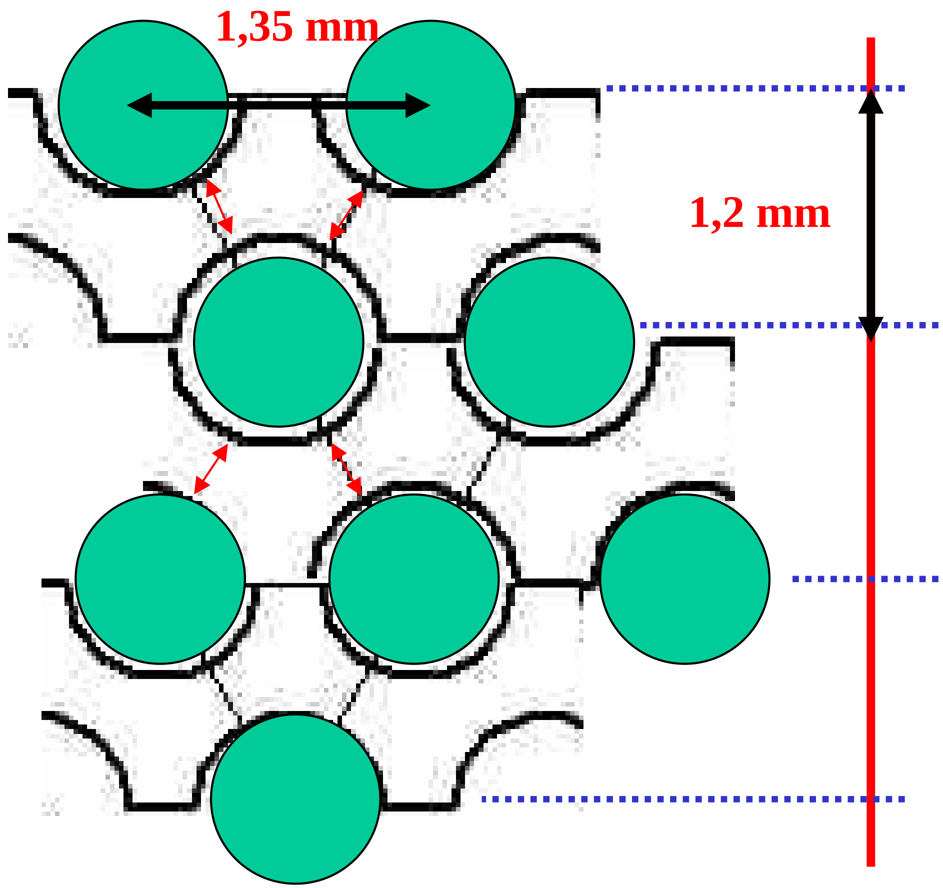
1mm diameter scintillating fibres embedded in grooved lead layers



Same construction technique as KLOE e.m. calorimeter

Lead-fibre composite





MICE

≈ 0.9 mm pitch ⊥ to the beam
1.35 mm pitch of lead foil grooving
0,3 mm Lead + 1 mm Fiber
$X_0 \approx$ 20 mm (estimated)

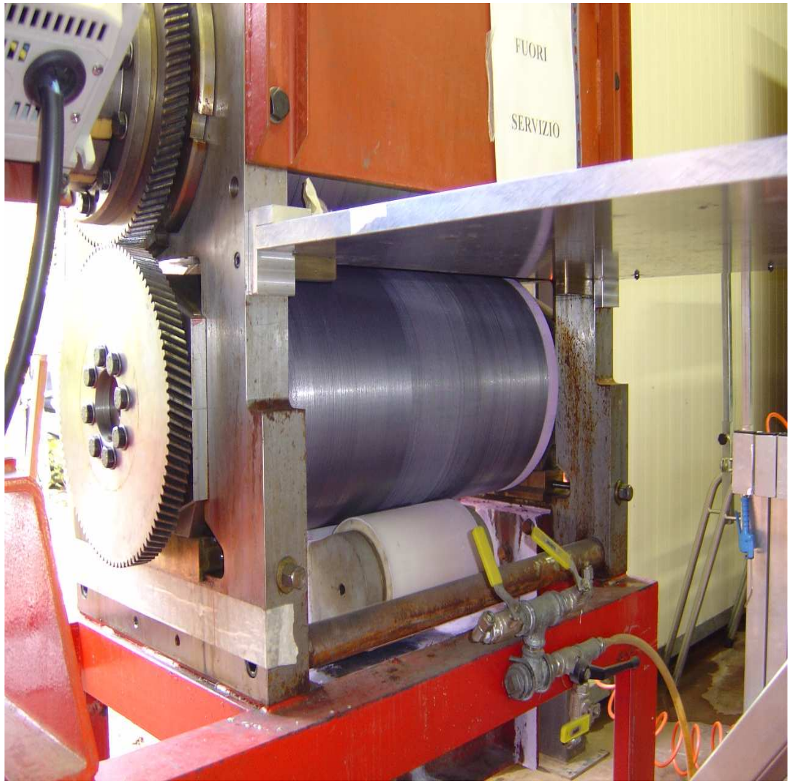
KLOE

≈ 1.2 mm pitch ⊥ to the beam
1.35 mm pitch of lead foil grooving
0,5 mm Lead + 1 mm Fiber
$X_0 \approx$ 12 mm (experimental)

Lead foils

Spools of lead foils of various thickness for tests (LNF & Roma III)

Lead-shaping machine



60 cm

The grooving rollers consist of 13 "disks" (*), 50 mm thick and 400 mm in diameter, made of hardened steel and ground to shape by a sintered diamond tool; the rollers are fixed by means of ball bearings (*) on a very rigid frame and are aligned and checked with a set of micrometers.

- Achievable thickness uniformity is around few tens of μm and
- The grooves can deviate from a straight line by less than 0.1 mm per foil length.

Designed and used for construction of KLOE EmCal (barrel modules)

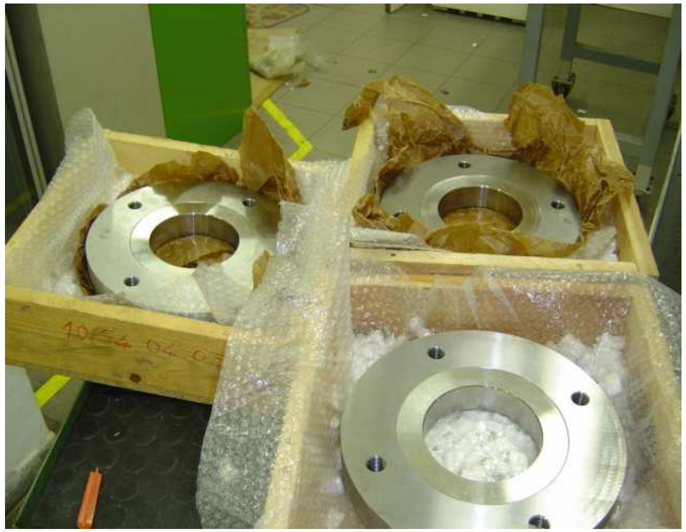
(*) require some maintenance and/or replacement

Machine dismantled for refurbishing

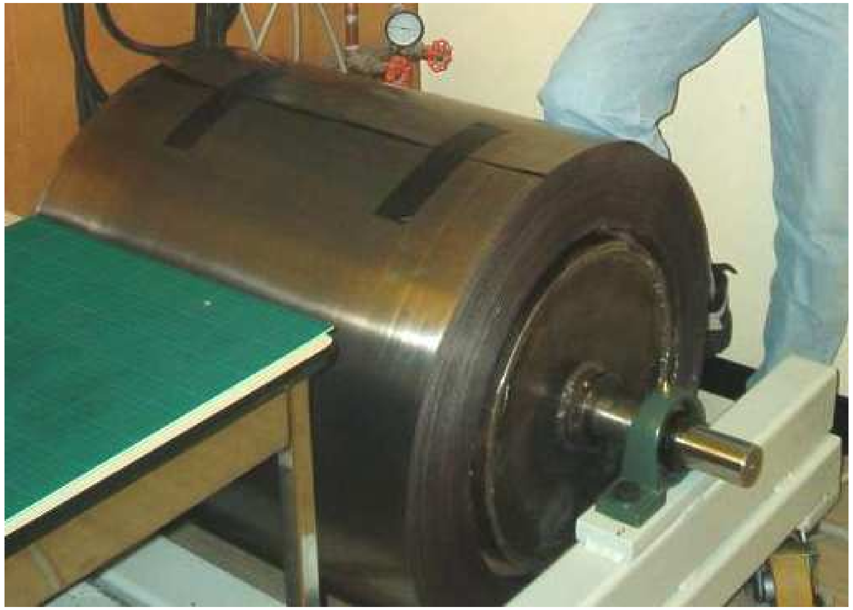
Balls bearing to be replaced

The grooving roller

Spare disks at Roma III (thanks to S.B.)

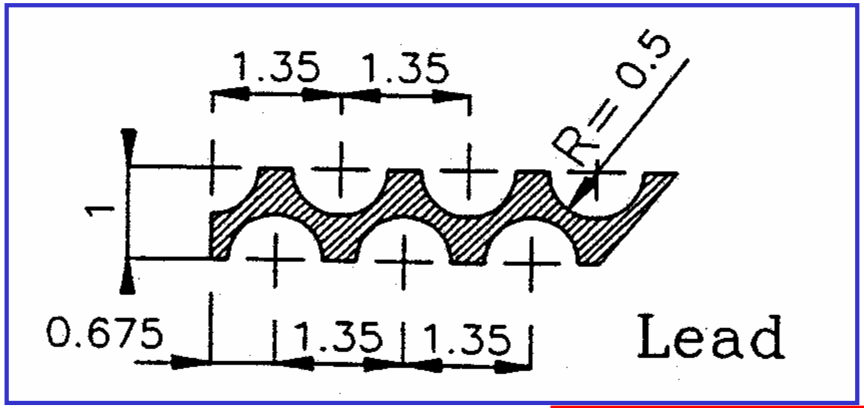


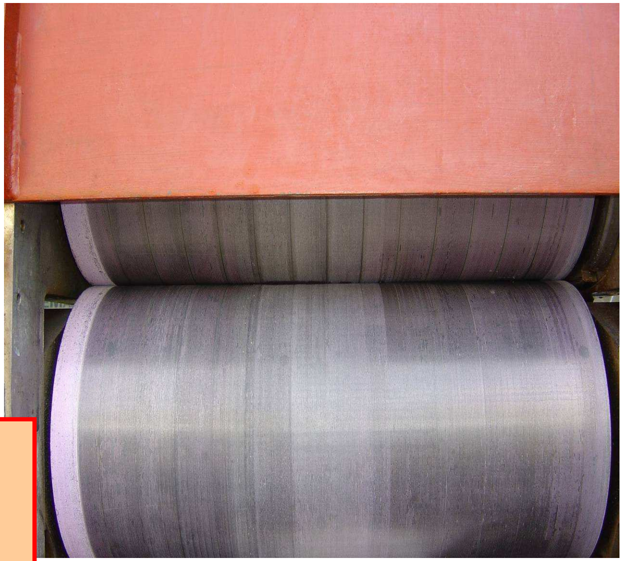
Lead-shaping



Lead spool

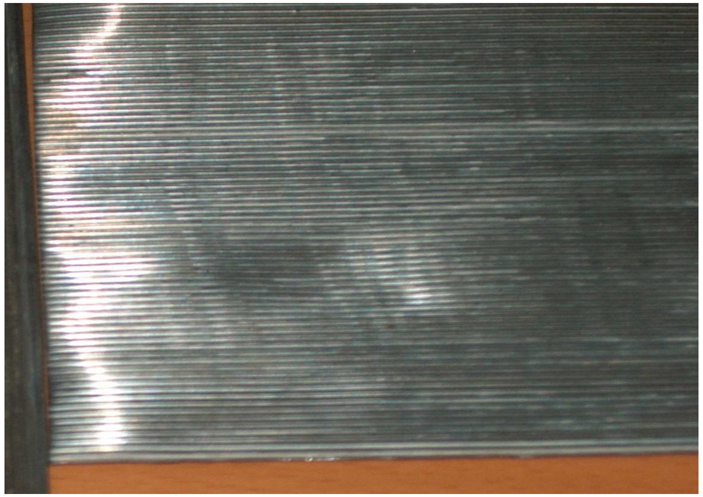
Big lead shaping machine





Rely on LNF for manufacturing

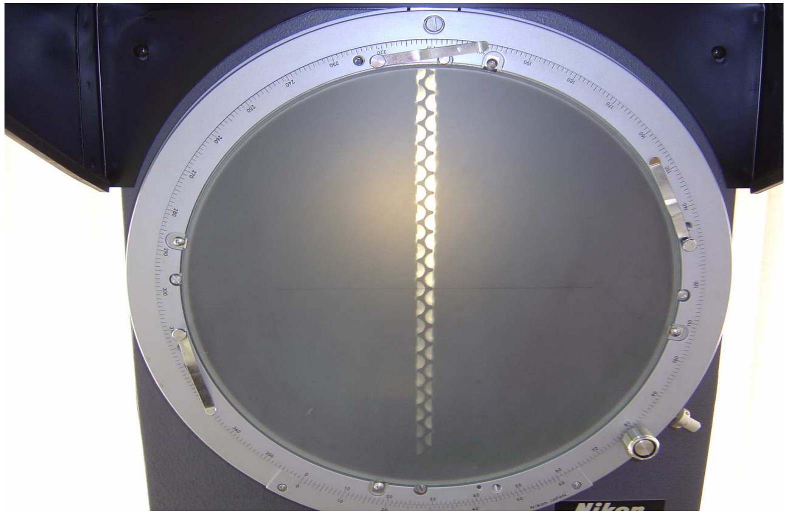
Tests at LNF Metrology lab



Lead grooved foil

Microscope

To be done at LNF



Enlarged view

Measurement

Scintillating fibres

- Pol.Hi.Tech is out of the game

- Offer by Kuraray
  only for SCSF 81 type
  (single and double cladding)

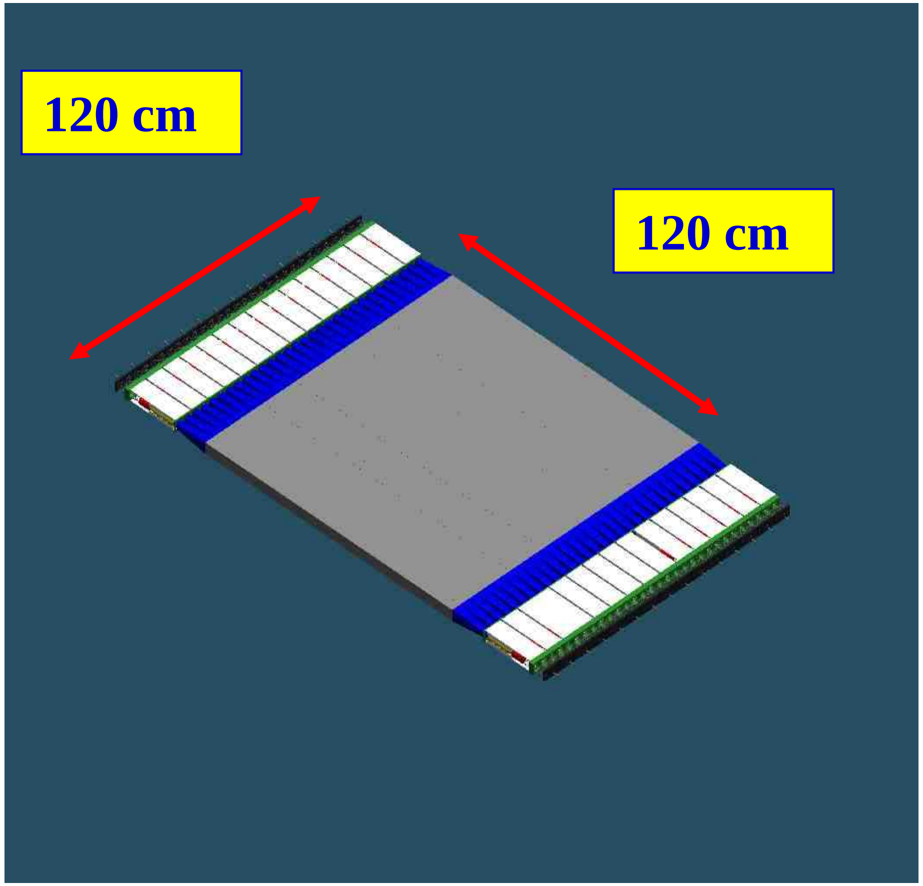
Scintillating Fibers[1]

Description	Emission Color	Emission Peak [nm]	Emission Spectra	Decay Time [ns]	Att. Leng.[2] [m]	Characteristics
SCSF-38, SCSF-38M	blue	428		2.3	>3.0	General Use
SCSF-81, SCSF-81M	blue	437	See the following figure	2.4	>3.5	Long Attenuation Length
SCSF-78, SCSF-78M	blue	450		2.8	>4.0	Long Att. Length and High Light Yield
SCSF-3HF(1500), SCSF-3HF(1500)M[3]	green	530		7	>4.5	3HF formulation for Radiation Hardness

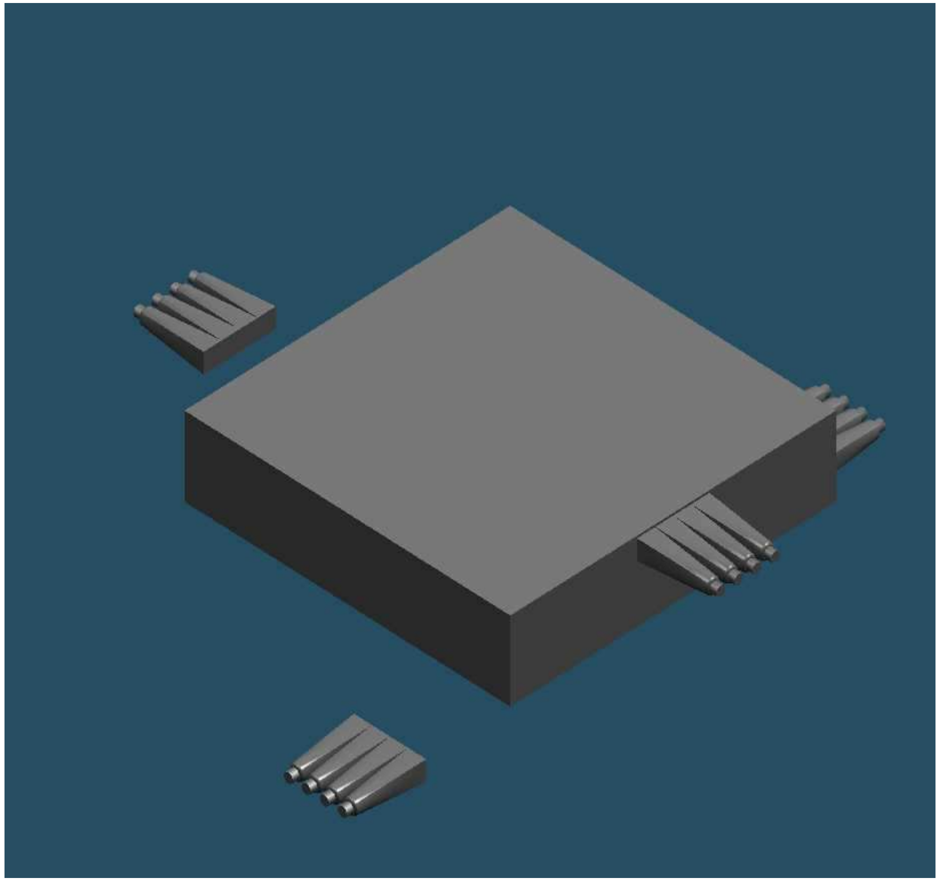
1) Test fibers are Non-S type, 1mmø.
2) Measured by using bialkali PMT and UV light (254nm). Quality control is made by another measurement of the transmission loss every batch.
3) For example, "3HF(1500)M" means the concentration of 3HF dye is 1500ppm, the cladding is Multi cladding.

- Foreseen cost for 25 km ≈ 20 keuro
  (tax free, transport included)

Calorimeter assembling

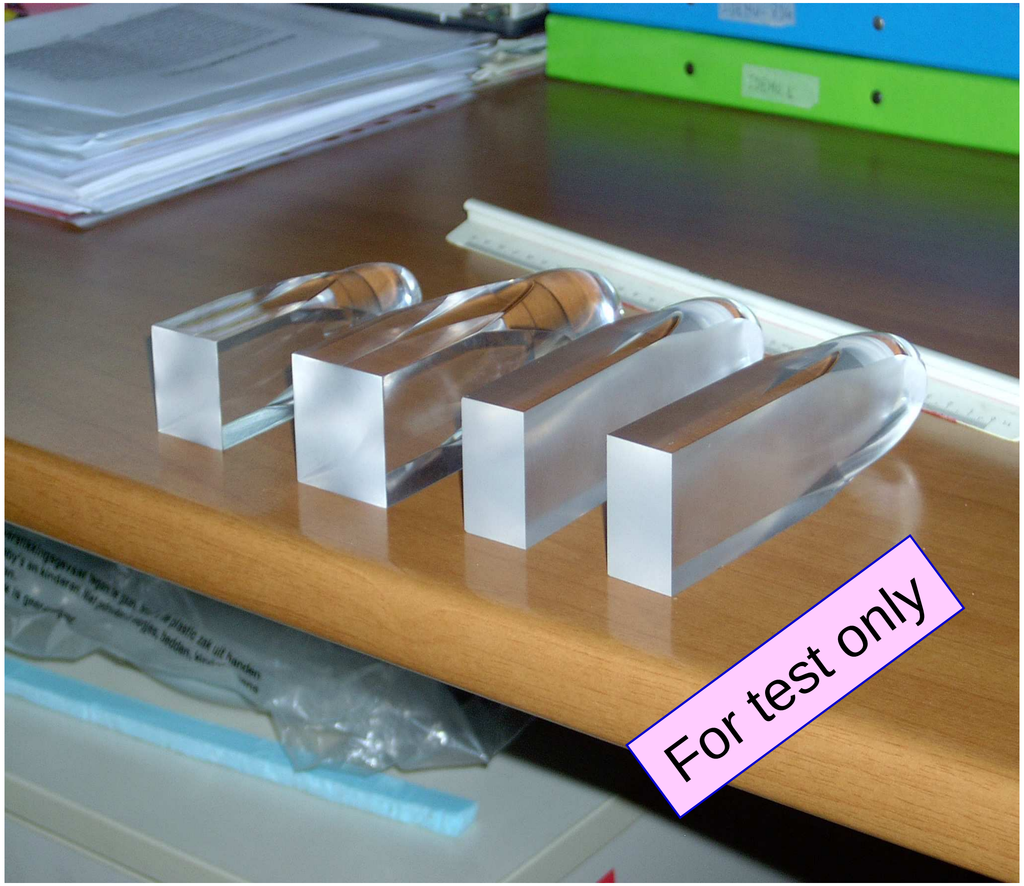


Example of Single plane with double side read out



Example of four planes superimposed alternating the fibers direction

Readout: Light guides



3.5 x 3.5 cm²

4 x 4 cm²

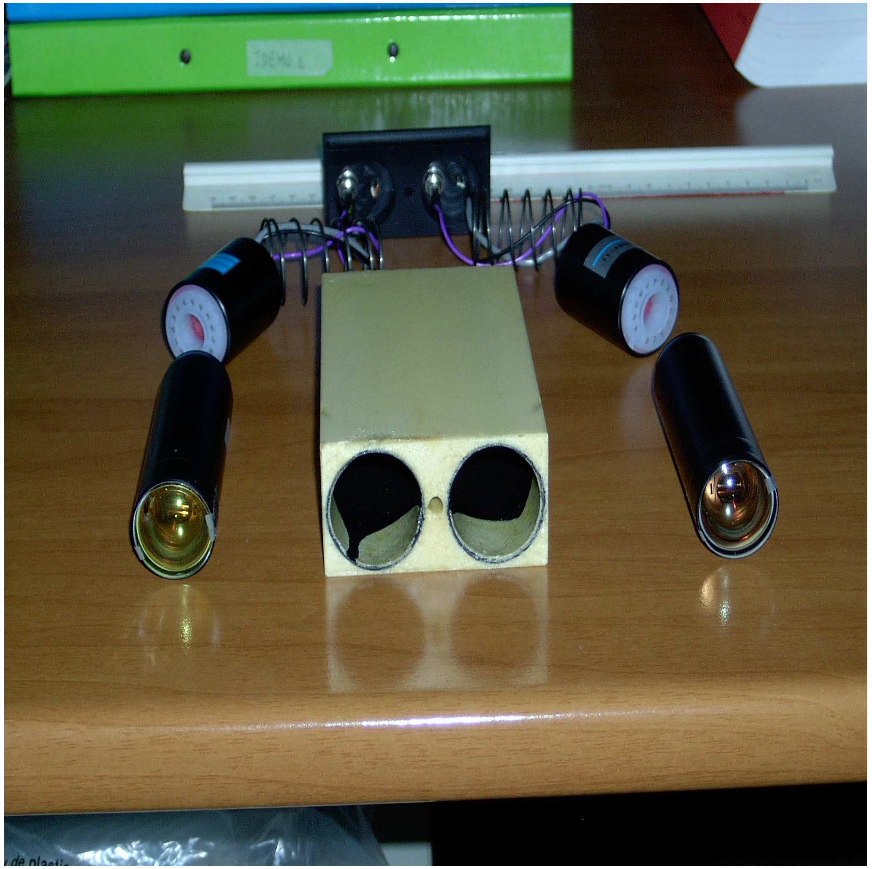
4 x 2.5 cm²

Final design to be defined accordingly with optimal cell size

(simulation studies in progress)

Readout: PMTs

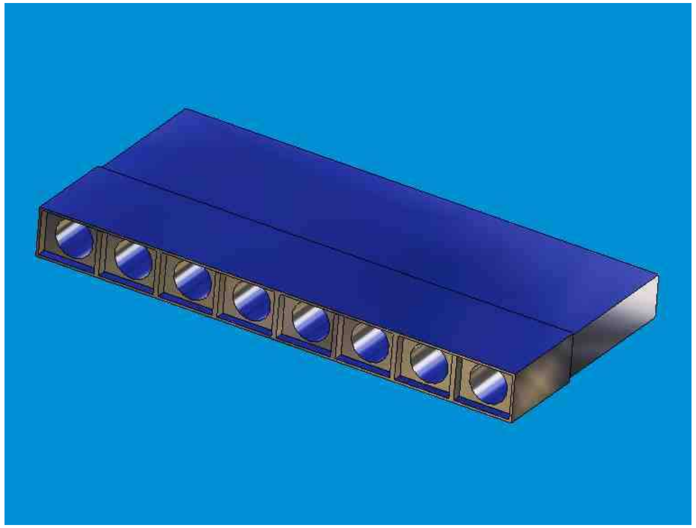
Photomultipliers and H.V. system previously used in **CHORUS** and **HARP**, then installed in **T2K**, now taken to **MINOS** (will be back in time!)



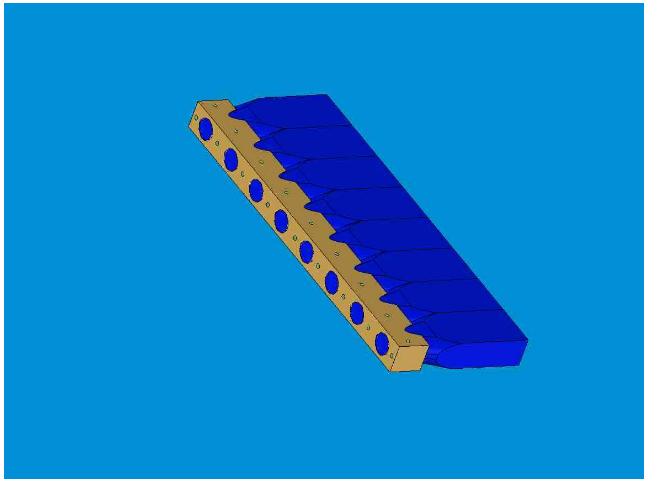
- Photomultipliers Hamamatsu 1355
- Voltage dividers 2624 type
- Housing boxes with 2 mu-metal shielding each
- Impedance adapters
- HV system available

  (to be recovered from Roma I and/or CERN)

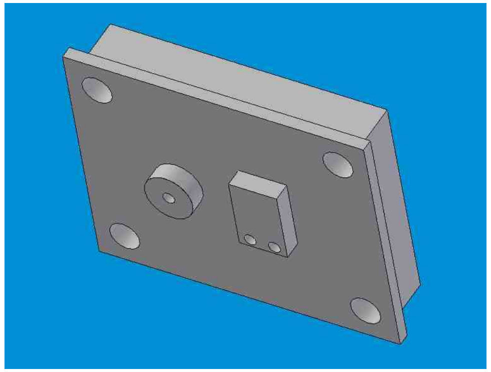
Components assembling

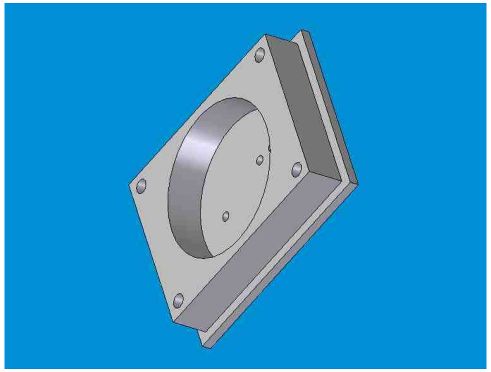


Multiple housing for PMs



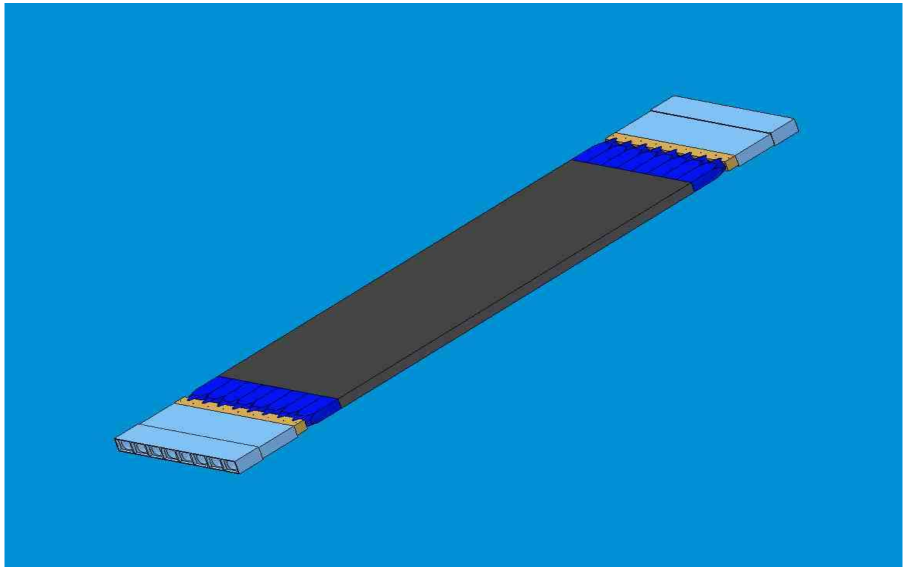
Light guides for a Sector





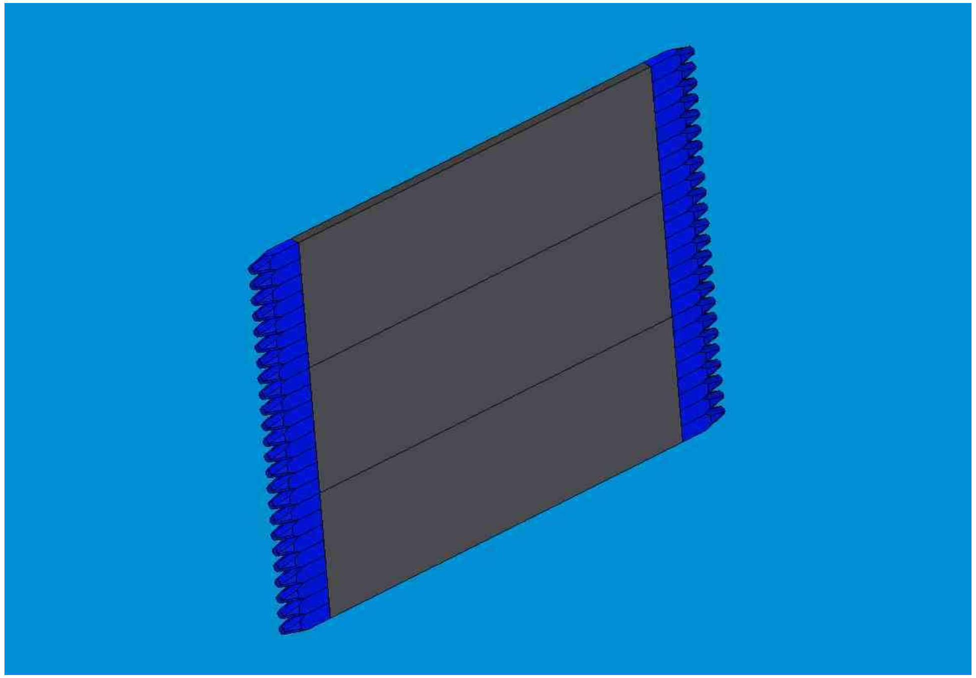
End plug (int. and ext.)

Plane assembling



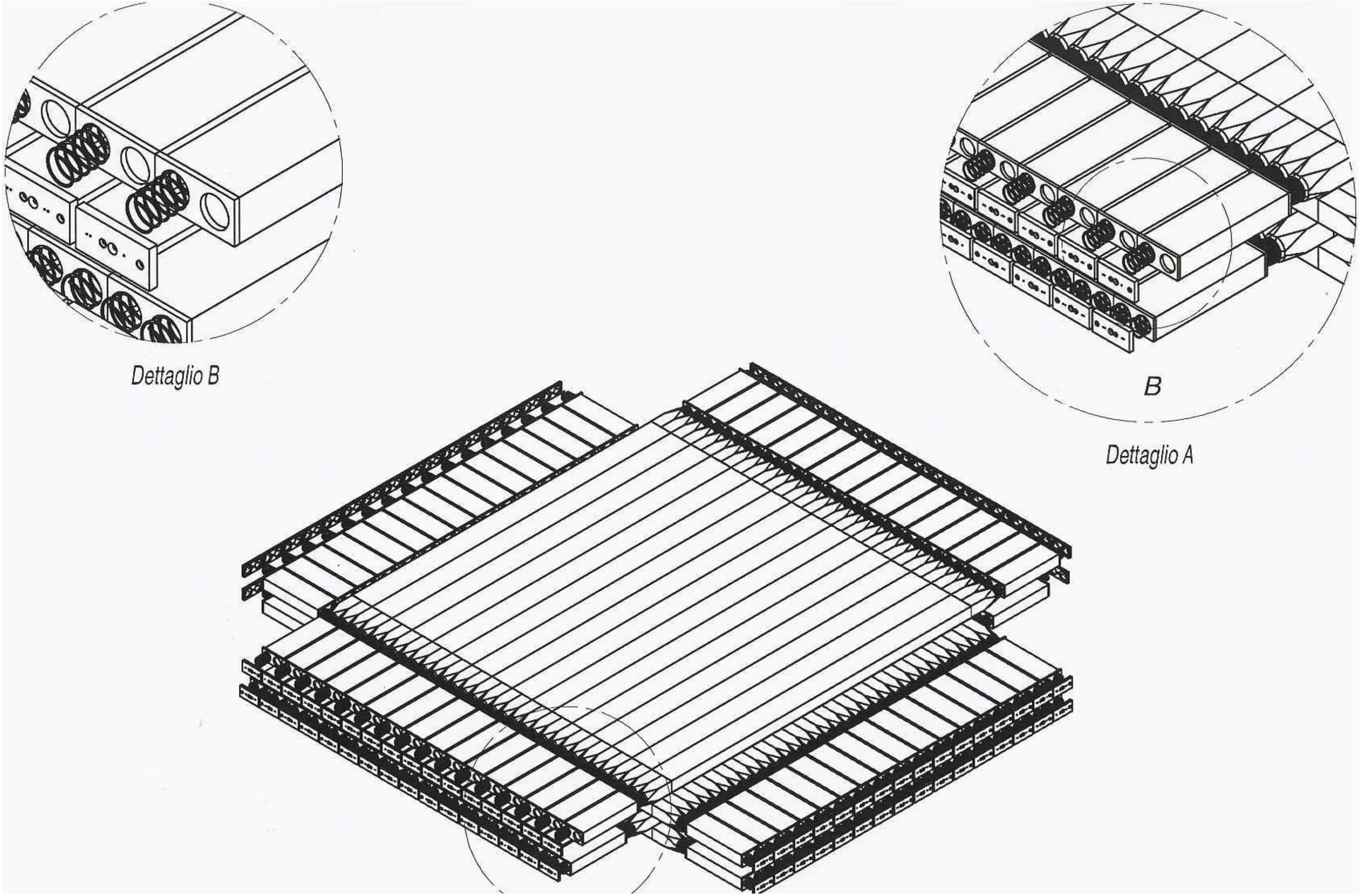
Sector active area 40x120 cm^2:

- Max transverse size set by grooving rollers width
- No limitation on longitudinal size

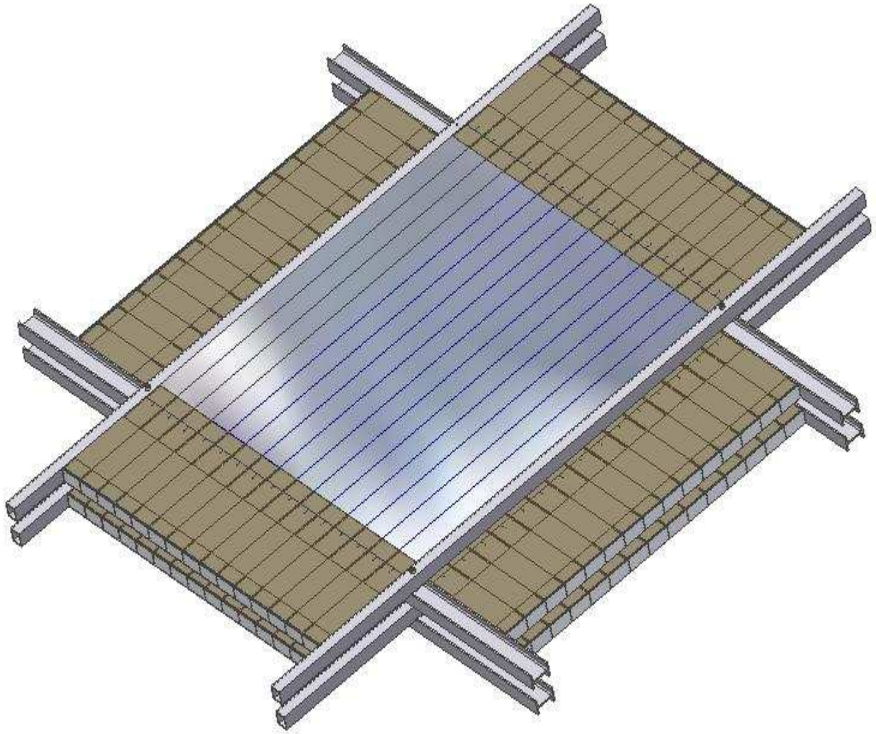


Plane active area120x120 cm^2

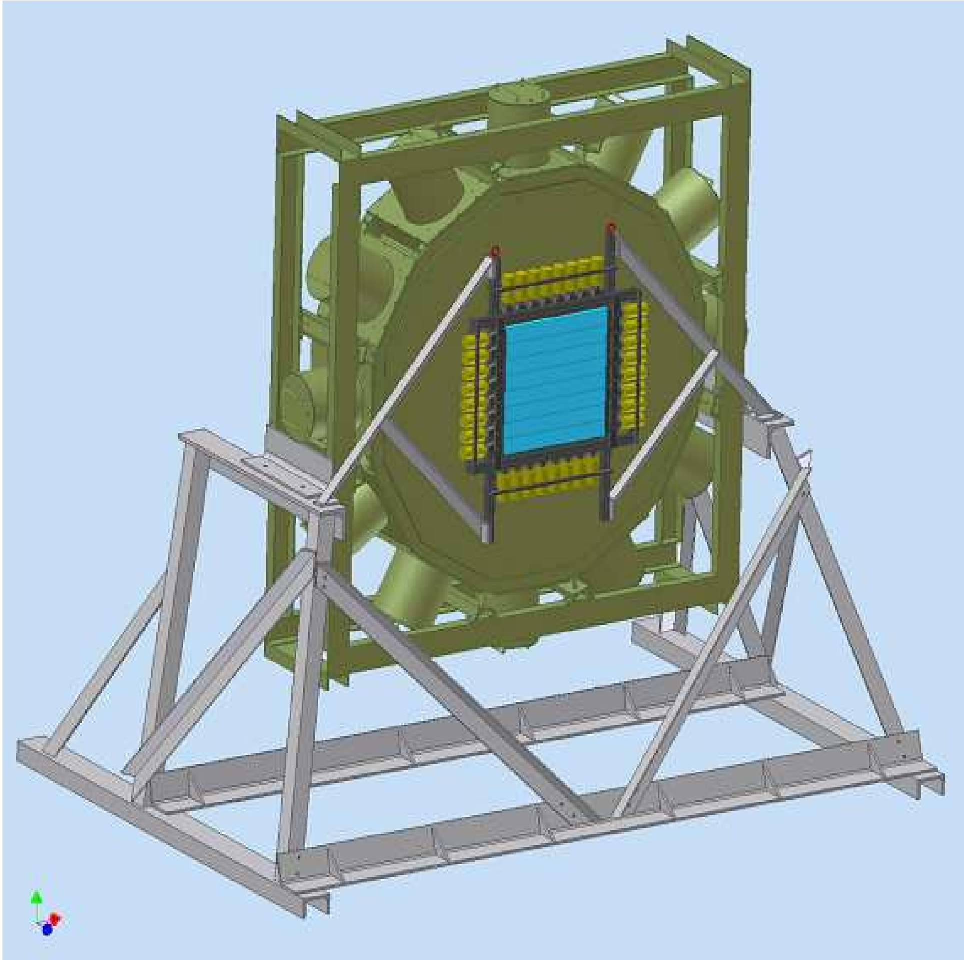
Calorimeter assembling



Calorimeter mounting



Calorimeter mechanical support structure



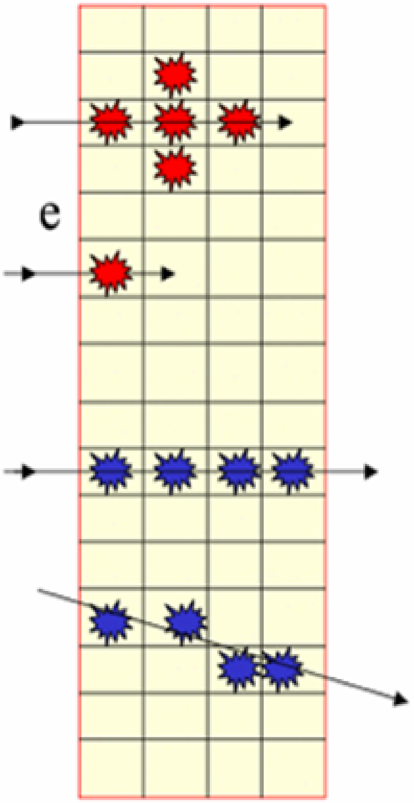
Insertion in the downstream PID support structure
(design under way by S.Yang)

Cost estimates

Raw Materials and Cables	Provider	Unit cost	Amount	Cost	Value
Fibers SCSF - 81	Kuraray	1,0	25.000	25.000	
Lead foils	Cofermetal	50	160	8.000	
Optical Glue BC600	Bicron	200	40	8.000	
Plexiglass for Light Guides	Policenter	15	240	3.600	
Mu-metal sheets	HARP-K2K	10	240		2.400
Boxes for PM & Dividers Housing	HARP-K2K	25	120		3.000
Cables and Connectors for HV and Signal	HARP-K2K	30	480		14.400
Miscellanea (Tools, Mylar, Consumable . .)				5.000	
Total				**49.600**	**19.800**
Instrumentation					
Photomultipliers (Hamamatsu price list)	HARP-K2K	600	240		144.000
Voltage dividers (Hamamatsu price list)	HARP-K2K	215	240		51.600
HV MainFrame SY127 (CAEN price list)	CHORUS-HARP	9.000	6		54.000
HV Power Supply A333 (CAEN price list)	CHORUS-HARP	600	240		144.000
Impedance Adapters	HARP	300	16		4.800
Splitters (t.b.d. with TOF)	CAEN	200	120	24.000	
CF Discriminators (t.b.d. with TOF)	CAEN	200	120	24.000	
VME Crate for ADC & TDC	CAEN	8.000	2	16.000	
TDC channels (same as TOF2)	CAEN	150	120	18.000	
ADC channels (same as TOF2)	CAEN	150	240	36.000	
DAQ modules V1718	CAEN	6.000	2	12.000	
Total				**130.000**	**398.400**
Construction (workshop operation and installation)					
Changes and Tuning Lead Swaging Machines				9.000	
Grooving of Lead Sheets	Gen. Tech.				
Fibers Glueing	Gen. Tech.				
Winston Cone Light Guides	Gen. Tech				
W C L G Coating and Glueing	Gen. Tech				
Total for External Workings @Gen. Tech.				85.000	
Modules Workings: Shaping, Polishing	O.M.C.C.			5.000	
Masks , Spacers , Mechanical Supports (a)				5.000	
Global Mechanical Support Frame (a)				5.000	
Installation costs (a)				5.000	
Patch Panel with HV & Signal Connectors (a)				5.000	
Total				**119.000**	
(a) = Estimate for 2007 budget year					
Gran Total				**298.600**	**418.200**

Electron vs muon identification

Pattern of visible energy



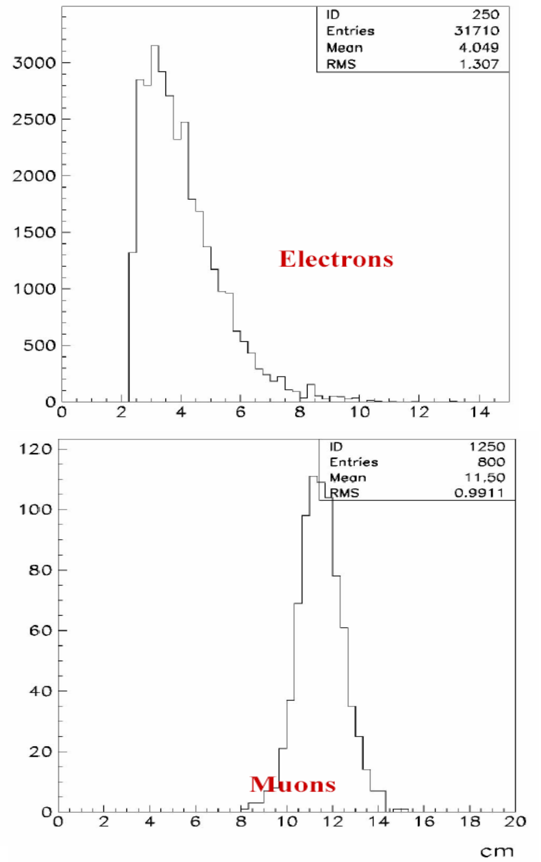
It's possible to distinguish **electrons** from **muons** by means of :

⇒ path reconstruction based on the energy released inside the calorimeter's elements

⇒ combination of cluster length, total energy, energy per plane …

Example: KLOE
Barycenter depth

$$Z_b = \frac{\sum Z_i E_i}{\sum E_i}$$



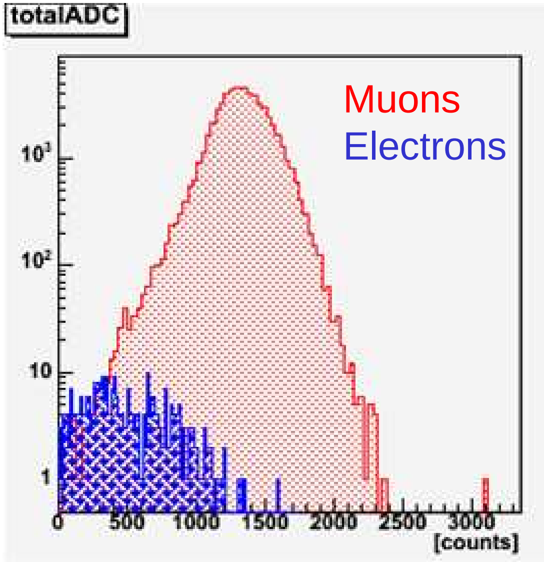
Calorimeter simulation and PID

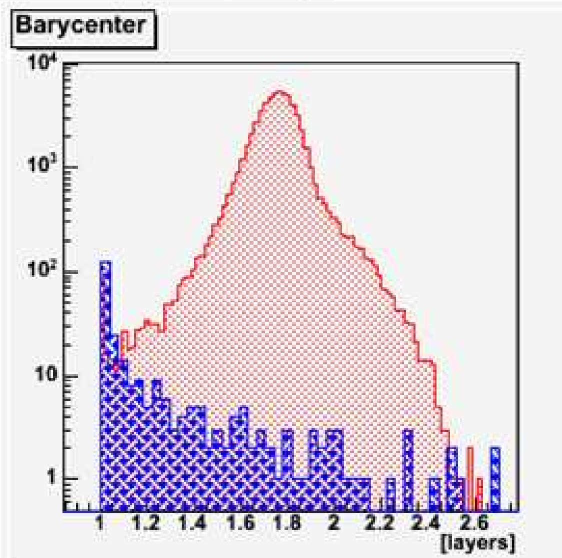
- Calorimeter simulation in G4MICE (by R.Sandstrom)
  - Full geometry (fiber-by-fiber)
  - Detailed digitization
  - Validation from comparison with KLOE data (in progress)

- Particle identification: separation of positrons from muons with a Neural Network
  - 11 input variables: total charge, shower barycenter depth, products and ratios of amplitudes at two sides in each layer
  - Excellent efficiency and purity achieved

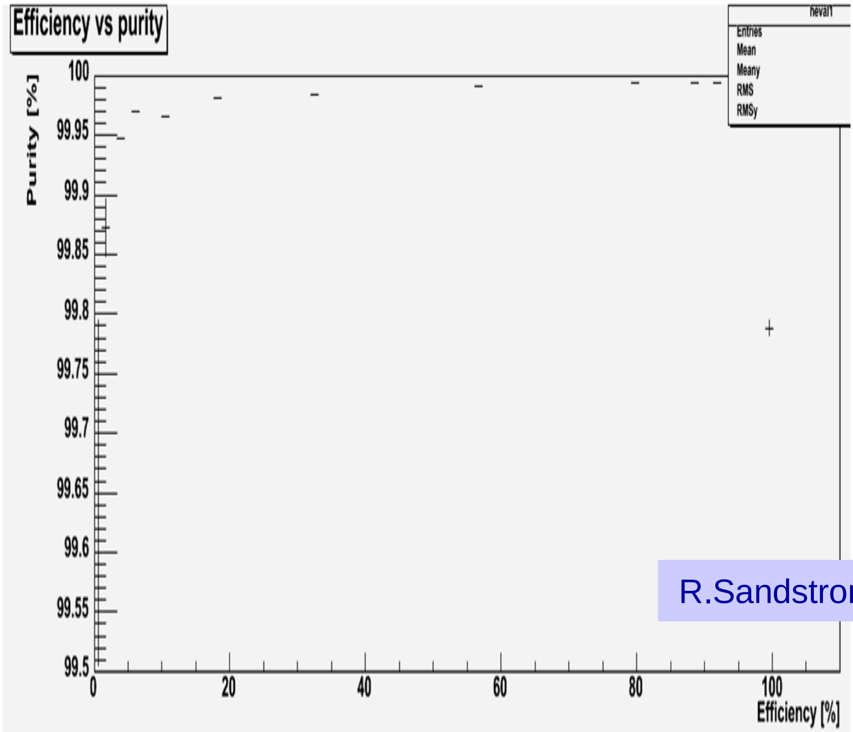
PID with a Neural Network

Two of the input variables





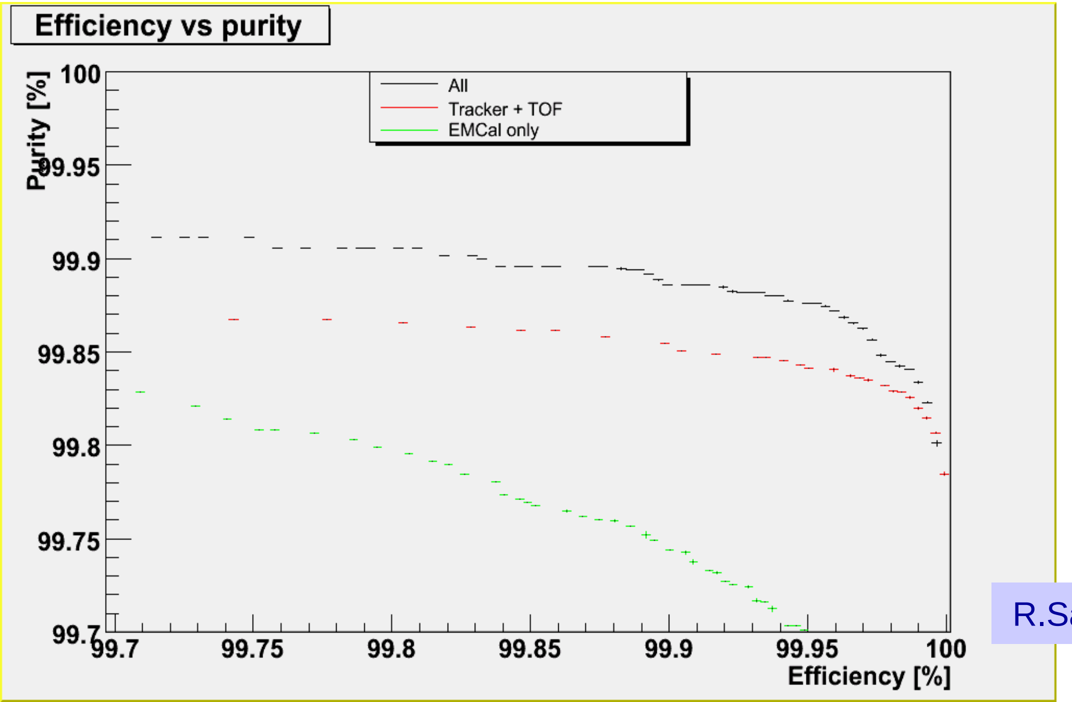
The result, with
- Muon momentum ~200 MeV/c
- full simulation of cooling channels and downstream detectors
- electrons from "true" muon decays (initial purity 99.542%)



PID with a Neural Network

Work in progress to achieve best possible μ tag downstream:

- Best use of full calorimeter information (incl. timing)
- Combination with other detectors (tracker,TOF, Ckov)



R.Sandstrom

EmCal Summary

- Fine grained calorimeter: scintillating fibers embedded in grooved lead foils
  - Lead layer thickness 0.3 mm
  - Read-out: 4 Layers, each read out by PMTs at both ends
  - Read-out cell size: 4x4 cm^2 or 3x5 cm^2
  - Total calorimeter size: 120 x 120 x (16 or 12) cm^3
- Muon/electron separation based on energy deposition and shower development
  - Identification algorithms studied with G4MICE
  - using a Neutral Network, purity and efficiency >99.9% canbe achieved
- PID capabilities are adequate for MICE requirements
- In progress: design optimisation